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Relative reinforcement from physical activity in real-world environments: a novel application of behavioral economics

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Abstract Behavioral economics suggests that individuals are likely to engage in a behavior if it is more reinforcing and readily available than other possible options. In real-world environments, sedentary behaviors are often more reinforcing and easily available than physical activities. In order to promote regular physical activity in an environment with sedentary alternatives, it is important to understand the proportion of overall reinforcement that is derived from physical activity (i.e., relative reinforcement, RR). Conceptually similar laboratory-research supports this notion, but applications to individual, real-world environments remain understudied. The current study used a novel survey-based approach to estimate the RR of common physical activities. Healthy adults ($N=348$, M age $=39.0 \pm 8.7$) from the United States completed an online survey between April–May 2020, including a modified activity survey with ten physically active and ten sedentary activities. Regression analysis showed that total RR of physical activity was related to greater physical activity levels when controlling for enjoyment and other covariates. Four factors were identified (household, conditioning, sports, and outdoor activities) using exploratory structural equation modeling, but internal consistency was limited when items were constrained to each factor in the structural equation model. Previous laboratory findings on overall RR of physical activity were replicated with the survey-based measure, but further improvement for relative reinforcement of different sub-domains of physical activity is needed. Researchers and practitioners can use this survey to determine attractive physical activities on the individual level that can compete with sedentary leisure activities.

Keywords Behavioral economics · Reinforcing value · Physical activity · Relative reinforcement · Sedentary behavior

Abbreviations

RR	Relative reinforcement
MVPA	Moderate-to-vigorous physical activity
LSI	Leisure score index
L-Cat	Leisure time activity categorical item
MET	Metabolic equivalent of task

Introduction

Lack of physical activity is one of the four leading risk factors for chronic diseases in the United States, including heart disease, cancer, and diabetes (Center for Disease Control and Prevention [CDC], 2020). One in six American adults suffer from at least one of these chronic diseases, putting them at risk for premature death (Booth et al., 2012; CDC, 2020). In order to minimize the health risks associated with insufficient physical activity, the *2018 Physical Activity Guidelines for Americans* recommend that adults engage in at least 150 min of moderate-to-vigorous physical activity (MVPA) per week (Piercy et al., 2018). However, according to self-report data, at least 40% of Americans do not meet these guidelines, and are insufficiently active (Booth et al., 2017; Hughes et al., 2019; Ussery et al., 2018).

Being sufficiently active requires choosing to engage in physical activity instead of sedentary behaviors, such as watching TV (Epstein & Roemmich, 2001). Behavioral

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economics models decision making in environments with competing alternatives (Epstein & Roemmich, 2001; Vara & Epstein, 1993; Vuchinich & Heather, 2003), and suggests that the decision to engage in one activity is influenced by the reinforcement obtained from the activity relative to competing alternatives in the environment, and the availability of reinforcing alternatives in the environment (Vara & Epstein, 1993; Vuchinich & Tucker, 1983). To predict decisions, behavioral economic approaches aim to examine how individuals allocate their resources (e.g., time; money) among all available options to derive the highest overall reinforcement (Rachlin et al., 1976). Predictions can be made by examining how much reinforcement is derived from one activity relative to overall reinforcement (i.e., relative reinforcement; Correia et al., 2002). Although, to date, the literature on reinforcement in the natural environment has only addressed substance use, a similar behavioral economic construct has been applied to exercise promotion. While *reinforcement* refers to the motivation to engage in a behavior in real-world environments (Correia et al., 2002), *reinforcing value* refers the amount of work someone is willing to do to get access to a reinforcer on progressive ratio schedules of reinforcement (Flack et al., b).

The reinforcing value of physical activity relative to the reinforcing value of sedentary behaviors (i.e., relative reinforcing value), is a predictor of physical activity levels in adults (Flack et al., 2017a, b). Adults who meet aerobic (e.g., bicycling, running) or muscle-strengthening (i.e., weight training) guidelines, also have greater relative reinforcing value of aerobic or muscle-strengthening activity, respectively (Flack et al., 2017a, b). Additionally, Flack et al. research (2017a) suggests that relative reinforcing value of physical activity is a stronger predictor than liking of physical activity. Thus, previous research suggests that enjoyment or liking of an activity is not sufficient to engage in it regularly, but reinforcement may a better predictor of a physically active lifestyle. Increasing relative reinforcing value of exercise can promote MVPA among overweight individuals (Flack et al., 2019b, 2020). Although this literature supports relative reinforcement as a relevant concept for physical activity, the current research is limited to reinforcing value as opposed to reinforcement in the real-world environment. Current literature focused on MVPA among inactive adults, and activities performed in a laboratory, including running on the treadmill, using the elliptical, or riding a stationary bike (Flack et al., 2017a, 2019a, b). However, for those who are inactive or insufficiently active, small increases in physical activity of any intensity provide substantial health benefits (U.S. Department of Health & Human Services, 2018), and some priority populations such as older adults or adults with obesity may find light physical activity more feasible and enjoyable. Assessing the reinforcement from various common physical activities in real-world environments relative to sedentary behaviors may provide an advanced understanding of decision-making surrounding physical activity.

Examinations of relative reinforcement in the natural environment have been successful when applied to substance use. Research suggests that high reinforcement of substance-free activities is related to decreased substance use (Correia et al., 2002; Hallgren et al., 2016), and increasing reinforcement of substance-free, goal-oriented behaviors that compete with substance use can reduce use (Murphy et al., 2005; Yurasek et al., 2015). To date, reinforcement of physical activity in real-world environments relative to reinforcement from sedentary behaviors has not been examined. In order to leverage the potential of this construct, it is important to examine survey-based measurement approaches that researchers and practitioners can use to identify reinforcing and available physical activities and increase the likelihood of choosing physical activity over sedentary behaviors.

The purpose of the current study was to examine whether relative reinforcement from physical activity as measured by a survey-based measure (Physical Activity Reinforcement Survey, PARS) is associated with physical activity in a sample of healthy adults of varying physical activity levels. In addition, internal consistency and concurrent validity of the PARS, which is modeled after the substance use version (Correia et al., 2002; Hallgren et al., 2016), were examined. Confirmatory factor analysis was used to examine the factorial validity of the PARS, and convergent validity was examined by comparing reinforcement of physical activity among those who do (i.e., active) and do not (i.e., inactive) meet physical activity guidelines (Flack et al., 2017a, b).

Methods

Participants and Procedure

An online survey was posted as a Human Intelligence Task (HIT) on the online platform Amazon Mechanical Turk (AMT) and made available for all AMT users located in the United States with an acceptance rate of 90% or higher. Participants completed a brief screening questionnaire assessing age and physical functioning ($N = 652$). Adults between 21 and 55 years of age who did not self-report any diagnosis for a physical health condition that may interfere with exercise were included in the study. The eligibility criteria served to confine the sample to healthy adults and minimize incomplete or nonsystematic responses. Eligible participants ($N = 348$) completed the survey between April 28, 2020 and May 25, 2020 and earned $15 for completing the 60-min survey. Data from all 348 participants were used in the analyses. The survey was administered via REDCap and the usability and technical functionality was tested by the research team prior to publication.

Compliance with ethical standards

All participants provided informed consent prior to completing the screening survey. The study procedures were approved by the University's institutional review board.

Measures

Demographic characteristics

Participants completed a basic demographic questionnaire including age, gender, race, ethnicity, and income.

Physical activity

To determine if participants met the 2018 Physical Activity Guidelines for Americans (Piercy et al., 2018), participants completed the Stanford Leisure-Time Activity Categorical Item (L-Cat) which includes six categories that describe different physical activity levels over the past 12 months (Kiernan et al., 2013). Categories 1–3 describe an inactive or insufficiently active lifestyle, while categories 4–6 describe a sufficiently active or very active lifestyle. In line with the initial study examining the consistency of pedometer-determined activity levels and the L-Cat (Kiernan et al., 2013), categories 1–3 were coded as *inactive*, and categories 4–6 were coded as *active*. In addition, minutes spent per day in light, moderate and vigorous activities during leisure time of a "typical 7-day period" were assessed using the Godin Leisure-Time Exercise Questionnaire (Gionet & Godin, 1989; Godin & Shephard, 1985). This questionnaire yields the leisure score index (LSI), which is an estimation of the total metabolic equivalents of tasks (MET) expended during mild, moderate and strenuous leisure time physical activity during a typical week (Amireault et al., 2015). The LSI can range from 0 to 238.

Sedentary leisure time

Self-reported sedentary time per day during the past 12-months was calculated as the sum of four leisure time domains (screen time such as TV, computer use, reading, and other) from the Sedentary Questionnaire (SIT-Q-12; Lynch et al., 2014).

Relative reinforcement from physical activity

Relative reinforcement from physical activity was assessed using a modified version of the Adolescent Reinforcement Survey Schedule for substance use (Correia et al., 2002; Hallgren et al., 2016). The Physical Activity Reinforcement Survey (PARS) consists of a list of activities that were rated on (1) frequency on a typical day during the past month on a Likert-type scale ranging from 0—"I did not do this activity" to 9– "9 h or more", and (2) enjoyment on a visual analog scale ranging from 1—"Extremely unpleasant" to 101—"Extremely pleasant". This scale was used to avoid raw values of 0 for enjoyment which would be problematic for the following steps. Consistent with previous literature (Correia et al., 2002), enjoyment was set to 0 when participants indicated that they did not engage in this activity, and reinforcement of each activity was calculated as the cross-product of frequency and enjoyment. Total frequency, enjoyment and reinforcement were calculated as the average across all activities. The relative reinforcement from each activity was calculated as the ratio of reinforcement from physically active behaviors to total reinforcement from all activities (i.e., reinforcement from physical activity/ [reinforcement from sedentary behaviors + reinforcement from physical activity]), and total relative reinforcement was calculated as the average of the relative reinforcement across all activities. The physically active items are shown in Table 3. The sedentary activities included watching television or videos, using the computer at work or doing paperwork, reading, socializing with friends or family, driving or riding in a car, or time in public transport, doing hobbies, e.g., craft, crosswords, using the computer during leisure time, computer games, play musical instrument or listen to music, and social media and texting.

Statistical analyses

All variables were checked for outliers as defined by 3.29 standard deviations above the mean, and windsorized with unit increments of 1 (Tabachnick & Fidell, 2013). Variables were then examined for deviations from skewness and kurtosis and transformed if the values were outside of the established limits (−2 and 2; Trochim & Donnelly, 2008).

Cross-sectional association—total relative reinforcement of physical activity

Multiple linear regression was used to examine whether total relative reinforcement (i.e., from all ten activities) was significantly related to physical activity as measured by the LSI when controlling for age, sex, income, and enjoyment of physical activity.

Exploratory factory analysis and structural equation model

Exploratory structural equation modeling (ESEM; Asparouhov & Muthén, 2009) was used to conduct an exploratory examination of the domains of relative reinforcement of physical activity. The models were estimated using Mplus (Muthén & Muthén, 2007) with individual raw data as input and the Satora–Bentler chi-square estimation for non-normal data, using 1000 iterations and a convergence criterion of 0.00005.

In ESEM, all the items are allowed to cross-load freely on all factors, unlike the conventional confirmatory factor analysis (CFA) approach, where items can only load on to a single factor (Asparouhov & Muthen, 2009). The number of factors was determined based on multiple indicators including eigenvalues, fit indices for the overall models, factor loadings, and interpretability of the factors. Standard errors for factor loadings and significance tests of factor loadings were examined. Geomin rotation was used to allow correlations between factors. Global model fit was evaluated using multiple indices to provide a reasonable assessment of model fit: The root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR) and their 90% confidence intervals (CI) should yield values close to 0.06, but not greater than 0.08, and the comparative fit index (CFI) should be close to 0.95 for acceptable model fit (Hu & Bentler, 1999). Path coefficients were significant if alpha = 0.05. The model was modified for modification indices greater than 5, indicating a significant contribution to lack of model fit with $p < 0.001$. Lastly, the composite reliability of the factors was calculated as the omega coefficient.

Cross-sectional associations—sub-domains of relative reinforcement of physical activity

Relative reinforcement from each domain (i.e., factor) was calculated as the average of the items. Pearson correlations and t-tests were used to examine correlations between relative reinforcement of all physical activities combined and in five domains and compare relative reinforcement between active and inactive participants. Levene's tests were used to check the homogeneity of variance, and Welch's t-test was used as needed.

Results

Participants

Participants (47.1% female, mean age = 39.0 ± 8.7) self-identified predominately as White or Caucasian (78.7%), approximately half completed a bachelor's degree (48.6%), and the majority were employed full-time (64.7%; see Table 1). Less than half of the participants were sufficiently active according to the L-Cat (40.8%), and the LSI indicated that participants expanded 41.4 ± 0.3 METs during a typical week.

Cross-sectional association—total relative reinforcement of physical activity

Total relative reinforcement of physical activity was significantly related to physical activity when controlling for age, sex, income and physical activity enjoyment ($F(5, 306) = 21.15$, adj. $r^2 = 0.25$, $p < 0.001$; see Table 2).

Exploratory structural equation model

The mean, variance, and Geomin-rotated factor loadings are shown in Table 3. The 2-factor and 3-factor models did not fit the data well (2-factor model: $RMSEA = 0.115$, 90% $C.I. = [0.097,0.134]$, $CFI = 0.784$, $SRMR = 0.060$; 3-factor model: $RMSEA = 0.091$, 90% $C.I. = [0.068,0.114]$, $CFI = 0.907$, $SRMR = 0.036$), but the 4-factor solution had acceptable model fit ($RMSEA < 0.01$, 90% $C.I. = [0.000,0.053]$, $CFI = 1.00$, $SRMR = 0.011$). Factor 1 was characterized by household-related activities (chores or housework, and gardening or yardwork). Factor 2 was characterized by and conditioning-based activities (aerobics, fitness or gym activities; lifting weights or body weight exercises; and running or jogging). Factor 3 was characterized by sports-related activities (swimming or diving; playing sports, e.g., tennis, soccer, basketball, etc.; and active hobbies, e.g., golf, dancing). Factor 4 was characterized by outdoor activities (active transport; active hobbies, e.g., golf, dancing; and outdoor activities). Thus, four observed factors were labeled as (1) household, (2) conditioning-based activity, (3) sports, and (4) outdoor activities.

One of the items significantly loaded on to two factors (item 9; active hobbies such as golf or dancing). This item was significantly related to both sports (factor 3) and outdoor activities (factor 4). This may be due to the overlap in the example that was given as part of the item (i.e., "playing golf"). For the final model, this item (9, active hobbies e.g., golf, dancing, etc.) was added to the factor sports (factor 3) because the factor loading was higher on this factor (0.506) compared to the outdoor activities factor 4 (0.311). Similarly, item 6 (running or jogging) loaded significantly on the conditioning-based activities (factor 2) and sports (factor 3). Swimming was added to factor 2 due to higher loading (0.328 vs. 0.292). Lastly, item 3 (aerobics, fitness or gym activities) loaded on to factors 2 (conditioning-based activities) and 4 (outdoor activities), but the loading on factor 4 was very low (0.188) compared to factor 2 (0.760), so item 3 was added to factor 2.

The highest relative reinforcement was derived from outdoor activities such as hiking or going for a walk (item 10), doing chores or housework (item 1), and active transport (item 8) (i.e., 30.7, 26.7 and 24.3% respectively). The lowest relative reinforcement was derived from swimming or diving (item 5), playing sports, e.g., tennis, soccer, basketball, etc.

Table 1 Participant characteristics by physical activity level

Variable		Total N = 348	Inactive (i.e., do not meet guidelines) n = 206 (59.2%)	Active (i.e., meet guidelines) n = 142 (40.8%)
	Mean (SD)/N (%)			
Age		39.0 (8.7)	39.5 (9.1)	38.4 (8.2)
Sex	Female	164 (47.1%)	103 (50%)	61 (43%)
Race/Ethnicity	Asian	32 (9.2%)	22 (10.7%)	10 (7%)
	Black or African American	21 (6%)	12 (5.8%)	9 (6.3%)
	Hispanic or Latino	14 (4%)	8 (3.9%)	6 (4.2%)
	Other	5 (1.4%)	3 (1.5%)	2 (1.4%)
	White or Caucasian	274 (78.7%)	159 (77.2%)	115 (81%)
	No response	2 (0.6%)	2 (1%)	0 (0%)
Education	Associates Degree	53 (15.2%)	34 (16.5%)	19 (13.4%)
	Bachelor's Degree (4-year)	169 (48.6%)	96 (46.6%)	73 (51.4%)
	Doctorate	8 (2.3%)	4 (1.9%)	4 (2.8%)
	High School	82 (23.6%)	54 (26.2%)	28 (19.7%)
	Master's Degree	31 (8.9%)	16 (7.8%)	15 (10.6%)
	None	1 (0.3%)	0 (0%)	1 (0.7%)
	Other	2 (0.6%)	2 (1%)	0 (0%)
	Professional School	2 (0.6%)	0 (0%)	2 (1.4%)
	N/A	0 (0%)	0 (0%)	0 (0%)
Occupation	Employed—full time	225 (64.7%)	124 (60.2%)	101 (71.1%)
	Employed—part time	23 (6.6%)	18 (8.7%)	5 (3.5%)
	Self-employed	75 (21.6%)	48 (23.3%)	27 (19%)
	Student—full time	2 (0.6%)	1 (0.5%)	1 (0.7%)
	Student—half time	2 (0.6%)	1 (0.5%)	1 (0.7%)
	Unemployed	18 (5.2%)	12 (5.8%)	6 (4.2%)
	No response	3 (0.9%)	2 (1%)	1 (0.7%)
Yearly income (self)	$0–$4999	8 (2.3%)	8 (2.3%)	5 (2.4%)
	$5000–$11,999	23 (6.6%)	23 (6.6%)	15 (7.3%)
	$12,000–$19,999	53 (15.2%)	53 (15.2%)	40 (19.4%)
	$20,000–$34,999	78 (22.4%)	78 (22.4%)	48 (23.3%)
	$35,000–$49,999	65 (18.7%)	65 (18.7%)	39 (18.9%)
	$50,000–$74,999	67 (19.3%)	67 (19.3%)	34 (16.5%)
	$75,000–$99,999	24 (6.9%)	24 (6.9%)	11 (5.3%)
	$100,000–$150,000	17 (4.9%)	17 (4.9%)	6 (2.9%)
	More than $150,000	3 (0.9%)	3 (0.9%)	1 (0.5%)
	No response	10 (2.9%)	10 (2.9%)	7 (3.4%)
Leisure-time physical activity (Leisure Score Index, LSI) in METs/week		41.4 (30.3)	26.4 (21.6)	63.5 (27.7)
Leisure sedentary time (in minutes/day)		430.6 (213.7)	447.1 (219.5)	406.0 (203.1)
Enjoyment from physical activity (1–101)		32.71 (16.0)	29.2 (16.5)	38.4 (16.1)
Reinforcement from physical activity (0–900)		71.7 (53.1)	58.4 (49.0)	90.8 (53.0)
Enjoyment from sedentary behaviors (1–101)		60.8 (12.3)	59.9 (12.0)	62.1 (12.7)
Reinforcement from sedentary behaviors (0–900)		197.8 (62.5)	190.9 (54.5)	207.6 (71.5)
Relative reinforcement[a] from physical activity (in % of total reinforcement)		0.36 (0.11)	0.33 (0.11)	0.39 (0.09)

Survey-data collected between April–May 2020 from adults residing the United States

Reinforcement derived from an activity was calculated as enjoyment * frequency of engagement during the past month

[a]Relative reinforcement derived from physical activity was calculated as the ratio of reinforcement from all physical activities to the total reinforcement derived from all active and sedentary activities combined

Table 2 Linear regression model

Variable	*b*	*SE B*	beta	*t*
(Intercept)	1.85	10.31		.18
Age	− .23	.18	− .07	− 1.31
Sex	.74	1.09	.01	.24
Income	1.69	.93	.09	1.81
PA—enjoyment	.67	.10	.36[a]	6.62
PA—relative reinforcement	53.81	15.62	.19[a]	3.45

Linear regression predicting physical activity (LSI; MET/week)

[a]indicates $p < .001$

(item 7) and active hobbies, e.g., golf, dancing (item 9; 5.7, 7.7 and 10.6%, respectively).

Structural equation model

For the structural equation models, latent factors were defined according to the domains observed in the exploratory model. The model provided acceptable model fit ($RMSEA = 0.069$, 90% $C.I. = [0.050, 0.088]$, $CFI = 0.913$, $SRMR = 0.051$). All indicator variables (i.e., items) loaded significantly on to each latent factor, confirming the findings of the Exploratory Structural Equation Model ($ps < 0.0001$), and all factors were significantly correlated ($ps < 0.042$).

Table 3 Factor loadings from the exploratory structural equation model

Item no	Item description	Relative reinforcement from physical activity				
		Reliability (Omega)	.72	.73	.63	.54
		Mean [Variance] *N = 335*	F1 Household	F2 Conditioning	F3 Sports	F4 Outdoor
1	Doing chores or housework	.267 [.023]	**.590**[a]	.080	− .071	.029
2	Gardening or yard work	.187 [.037]	**.797**[a]	− .031	.074	− .001
3	Aerobics, fitness or gym activities	.234 [.044]	.028	**.760**[a]	− .002	**.188**[a]
4	Lifting weights or body weight exercises	.191 [.043]	− .071	**.801**[a]	.010	− .030
5	Swimming or diving	.052 [.017]	.114	.041	**.468**[a]	.008
6	Running or jogging	.140 [.042]	.093	**.328**[a]	**.292**[a]	− .092
7	Playing sports (e.g., tennis, soccer, basketball, etc.)	.077 [.025]	.023	− .006	**.705**[a]	.012
8	Active transport (e.g., walking, cycling)	.243 [.044]	− .012	.154	.157	**.449**[a]
9	Active hobbies (e.g., golf, dancing, etc.)	.106 [.032]	− .072	.004	**.506**[a]	**.311**[a]
10	Outdoor activities e.g., (hiking, going for a walk)	.307 [.040]	.108	− .041	− .023	**.714**[a]

Geomin-rotated factor loadings from the exploratory structural equation model of relative reinforcement from physical activity

[a]$p < .05$

Cross-sectional associations—sub-domains of relative reinforcement of physical activity

Correlations

The correlations between relative reinforcement from household, conditioning, sports, and outdoor activities with sedentary behavior and leisure time physical activity are shown in Table 4. All sub-domains were positively related to relative reinforcement from all physical activities combined. Relative reinforcement from conditioning, sports, and outdoor activities were positively associated with leisure time physical activity. Relative reinforcement from outdoor activities was also negatively related with sedentary time.

T-tests

Means and 95% confidence intervals of overall relative reinforcement, and in five domains are shown in Fig. 1. Levene's tests were significant for conditioning activities and outdoor activities, indicating non-homogeneity of variances. For these variables, a Welch t-test was conducted, and regular two-sample *t*-tests were conducted for the other variables. Comparisons between active and inactive participants showed that active participants derived significantly higher relative reinforcement from all physical activities combined ($t(333) = -5.50$, $p < 0.001$, Cohen's $d = 0.62$) and from conditioning activities ($t(263.39) = -8.55$, $p < 0.001$, Cohen's $d = 0.96$). Groups did not differ in relative reinforcement derived from the other domains (ps > 0.05, Cohen's ds < 0.12).

Discussion

Behavioral Economics suggest that the relative reinforcement from physical activity compared to sedentary behaviors influences the decision to engage in physical activity (Epstein & Roemmich, 2001). The current study replicated previous laboratory findings using a survey-based measure of relative reinforcement of physical activity, showing that higher relative reinforcement of physical activity is related to greater physical activity levels, above and beyond enjoyment of physical activity (Flack et al., 2017a). Additionally, this study demonstrates a first step towards developing a survey-based measure of relative reinforcement of various physically active behaviors activities in the individual, real-world environments. The structural equation model suggested a four-factor solution including household, conditioning-based activities, sports, and outdoor activities. The internal reliability was acceptable for household and conditioning-based activities, and low internal reliability was found for sports and outdoor activities, showing the need for future research to further develop this measure. One opportunity for improvement became evident in the cross-loading of item 9 (active

Table 4 Cross-sectional associations

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Physical activity (LSI; MET/week)	41.40	30.28							
2. Sedentary leisure time (min/day)	430.64	213.68	.07						
			[−.04, .18]						
3. Relative reinforcement—combined	0.36	0.11	.34[b]	−.17[b]					
			[.24, .43]	[−.27, −.06]					
4. Relative reinforcement—household	0.23	0.15	.04	−.10	.52[b]				
			[−.07, .15]	[−.21, .01]	[.44, .60]				
5. Relative reinforcement—conditioning activities	0.19	0.17	.55[b]	−.04	.47[b]	.17[b]			
			[.47, .62]	[−.15, .07]	[.38, .55]	[.06, .27]			
6. Relative reinforcement—sports	0.08	0.12	.20[b]	.09	.26[b]	.22[b]	.42[b]		
			[.09, .30]	[−.02, .19]	[.16, .36]	[.12, .32]	[.33, .50]		
7. Relative reinforcement—outdoor activities	0.28	0.17	.26[b]	−.13[a]	.44[b]	.23[b]	.17[b]	.34[b]	
			[.15, .36]	[−.23, −.02]	[.34, .52]	[.12, .33]	[.07, .28]	[.24, .43]	

Cross-sectional associations of relative reinforcement from all physical activities combined, and of chores, conditioning-based activities, sports, and outdoor activities with self-reported physical activity and sedentary behavior

[a]Relative reinforcement was calculated as the ratio of reinforcement from one type of activity to the total reinforcement derived from all active and sedentary activities combined; M and SD are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. [a]Indicates $p < .05$; [b]indicates $p < .01$

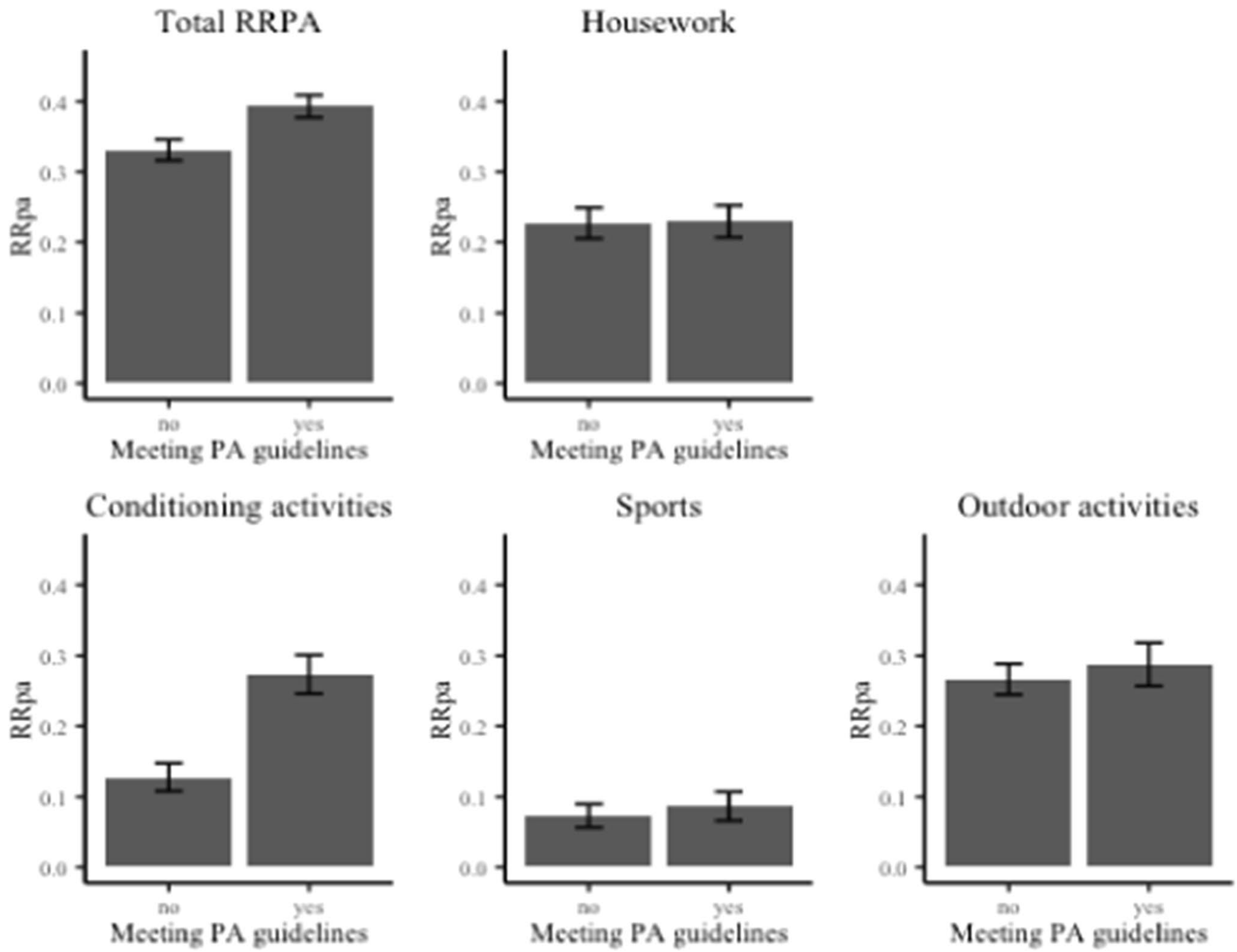

Fig. 1 Relative reinforcement from physical activities by adherence to the 2018 Physical Activity Guidelines. Total relative reinforcement from all physical activities combined, and of household, conditioning-based, sports, and outdoor activities by physical activity level (insufficiently active vs. meeting physical activity guidelines; bars represent means with 95% confidence intervals). *Note RRPA* relative reinforcement from physical activity, *PA* physical activity

hobbies, e.g., golf, dancing) on both factors 3 (sports) and 4 (outdoor activities) amidst the otherwise clear factor structure. Future iterations should avoid using specific examples and specify the distinction between sports for leisure (i.e., active games outside of an institution) and professional sports (i.e., as organized by institutions or as primary occupation).

Potential implications for tailored physical activity promotion

The preliminary findings on the concurrent validity of relative reinforcement of physical activity can serve as a starting point for future research. While the PARS yielded consistent results with previous research (Flack et al., 2017a, 2019b) when examining total relative reinforcement of physical activity, improvements of the measure are needed when examining relative reinforcement of physical activity sub-domains. Convergent validity was demonstrated by cross-sectional associations with physical activity level that are consistent with previous findings (Flack et al., 2017a, 2019b), showing a positive association with leisure time physical activity, and a negative relationship with sedentary leisure time. Additionally, relative reinforcement from conditioning-based activities (e.g., aerobics, gym-related activities, weightlifting and body weight exercises, and running or jogging), and all physically active behaviors combined was higher among active participants compared to inactive participants. Unlike conditioning-based exercises, there was no difference in relative reinforcement from household, active transport, and outdoor activities between the two groups. One possible interpretation is that conditioning-based exercises have uniquely reinforcing properties that are valued higher than sedentary behaviors among sufficiently active adults. The current findings support the importance of making conditioning-based exercise more reinforcing to promote sufficient physical activity (; Flack et al., 2017a, 2019a, 2019b). Future research should examine ways to increase the reinforcement obtained from these types of activities among inactive adults and encourage sacrificing a sedentary time to engage in conditioning-based activities. One way to increase relative reinforcement from conditioning-based activities may be to develop greater tolerance for discomfort during MVPA (Ekkekakis et al., 2011; Flack et al., 2019b).

In addition to MVPA, light physical activity can be especially beneficial for adults who are sedentary and engage in no physical activity (Buman et al., 2014; Qiu et al., 2020). Results suggest that outdoor activities and active transport may provide a reinforcing alternative to sedentary behaviors among inactive and sedentary adults. This finding is particularly relevant within the current context of COVID-19, as outdoor activities are considered one of the few physical activities that can safely be performed outside of the home (Sallis et al., 2020). Among the inactive and sedentary population, one promising approach may be to increase the reinforcement derived from outdoor activities to replace sedentary time.

Lastly, one important question to consider in addition to the present analyses is what drives the motivation to be active when selected sedentary activities are available. We compared frequency, enjoyment, and reinforcement between the two groups (sufficiently vs. insufficiently active), and found that sufficiently active individuals enjoy and derive more reinforcement from all activities than insufficiently active adults, with the exception of TV watching and playing video games. Additionally, sufficiently active individuals more frequently engaged in socializing and playing instruments or listening to music, while insufficiently active individuals reported both lower frequency and enjoyment of these behaviors. This may suggest that these two behaviors are particularly strong competitors of PA, and may even be associated with lower enjoyment and reinforcement of any other activities. There is literature supporting the addictive characteristics of these behaviors (Bassett et al., 2020; Sussman & Moran, 2013), which should further be examined in the context of physical activity promotion for those who derive an excessive amount of reinforcement from these behaviors.

Study strengths and limitations

This study was the first to examine relative reinforcement from various physical activities in real-world environments and provides a novel approach for future research on tailored physical activity promotion. The present results should also be interpreted in consideration of limitations. The survey-based assessments of physical activity and sedentary behavior are prone to subjective bias and overreporting of physical activity, and future research should examine the convergent validity with objectively measured physical activity. In addition, the convergent validity with relative reinforcing value as measured by the laboratory task should be examined. The factor structure may also depend on the sample, and future research should examine the new iteration of this measure in different samples. The majority of the sample self-identified as Caucasian or White (78.7%). It is important to examine relative reinforcement from physical activity among different ethnicities and cultures, and future studies should start to examine African-American and Hispanic populations, who report the highest rates of physical inactivity (Hughes et al., 2019). This study was conducted with healthy adults, for whom physical activity is important to prevent future health problems. Other populations such as cancer survivors, people with disability or older adults can benefit from physical activity, and future research should include these populations. Lastly, this sample was limited to workers on Amazon Mechanical Turk, and future studies should recruit adults from the general public and local communities to inform interventions.

The findings regarding two particular behaviors (swimming and household activities) should be noted. Firstly, although it is likely that adults swim laps to be physically active rather than compete professionally, swimming loaded on both factors "Sports" and "Fitness". Swimming may have loaded on to the factor "Sports" because of the similarly low relative reinforcement of the three items on this factor, which may partly be driven by the low frequency of engagement in the sample. Similarly, the results suggest that household activities has a greater reinforcement than active hobbies and playing sports, which may partly be driven by the high frequency of this activity. Future iterations of this measure should find ways to improve the measurement of frequency to address these natural variations. Lastly, future research should examine whether different sedentary behaviors compete differently with physical activity. For example, do physically active adults derive as much reinforcement from watching TV as physically inactive adults, or do physically active adults find other activities such as socializing or reading more reinforcing? The current data also suggested that physically active adults have higher reinforcement of either type of activity in general. Future research should examine how relative reinforcement of physical activity is related to enjoyment and reinforcement from other activities including passive activities such as TV watching, and also non-passive activities such as prosocial or personal development activities. Despite these limitations, the study was adequately powered and includes adults with a wide range of physical activity level which is are representative of the U.S. (Ussery et al., 2018), and thus provides important preliminary data for future research to improve and tailor physical activity programs.

Conclusions

The current findings support a novel behavioral economic approach to physical activity promotion suggesting that relative reinforcement from physical activities compared to sedentary behaviors may be a determinant of physical activity. The findings support high reinforcement (i.e., motivation to engage in a behavior measured as enjoyment and frequency of engagement) from conditioning-based exercises to meet physical activity guidelines, and high reinforcement derived from outdoor activities and active transport to replace sedentary behaviors. Previous laboratory findings were replicated with the survey-based measure (PARS) when examining overall relative reinforcement of physical activity, but further improvement of the measure is needed to examine relative reinforcement of different sub-domains of physical activity. Future studies should focus on advancing the development of an improved measure, and further examine physical activity promotion in the context of behavioral economics.

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Availability of data and material The data that support the findings of this study are available from the corresponding author [RKF], upon reasonable request.

Code availability The code is available from the corresponding author [RKF], upon reasonable request.

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Consent to participate Informed consent was obtained from all individual participants included in the study. Prior to completing the screening questionnaire, participants were shown the informed consent form, including a short overview of the study, approximate time to completion, compensation, their rights as participants and contact information for further questions. Participants were informed that they were not compensated for completing the screening survey only. The consent form was available as a PDF download. After reviewing the informed consent document and agreeing to participate, participants were redirected to the screening survey to determine eligibility for the study.

Consent for publication Not applicable because all data is de-identified.

Ethics approval All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Institutional Review Board (IRB) of the University of Florida (IRB Number 202000323; Date Approved 4/21/2020).

Human and animal rights This research was conducted in accordance with the Helsinki Declaration as revised in 2008.

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